ChatGPT M.D.: Is there any room for generative AI in neurology and other medical areas?

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Summary

Background: In recent months, ChatGPT, a general artificial intelligence, has become a cultural phenomenon in the scientific community and general audience as well. A widely increasing number of papers discussed ChatGPT as a powerful tool in scientific writing and programming but its use as a medical tool is largely overlooked. Here we show that ChatGPT can be used as a valuable and innovative augmentation in modern medicine, especially as a diagnostic tool. **Methods:** We used synthetic data generated by neurological experts to represent descriptive anamneses of patients with known neurology-related diseases, then the probability for an appropriate diagnosis made by ChatGPT was measured. To give clarity to the accuracy of the AI-determined diagnosis, all cases have been cross-validated by other experts and general medical doctors as well. **Findings:** We found that ChatGPT-determined diagnoses

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can reach the probability level of other experts, furthermore, it surpasses the probability of an appropriate diagnosis if the examiner is a general medical doctor. Our results support the efficacy of general artificial intelligence like ChatGPT as a diagnostic tool in medicine. **Interpretation:** In the future, it might be a useful amendment in medical practice, especially in overwhelmed fields and/or areas requiring fast decision-making like oxiology and emergency care. **Fundings:** The project was financially supported by the OTKA FK_22 143326 grant from the National Research, Development, and Innovation Office of the Hungarian Government.

Research in context

Evidence before this study

To date, only a few artificial intelligence tools have been translated into clinical practice due to slow or complicated applications in real-life scenarios. However, large language models and generative artificial intelligence are becoming more and more available in science and medicine as well. One of the newest large language models, ChatGPT has become a cultural phenomenon in science. PubMed entries with ChatGPT emerge rapidly, however, most of these researches focus on the application of this novel technology in scientific writing. However, only a few studies suggest its possible application in medicine. Using such artificial intelligence can help medical doctors to create patient discharge documents, or even write radiology reports, or suggest antimicrobial agents. The latest findings showed that ChatGPT can pass the United States Medical Licensing Examination therefore it might be useful in more complicated clinical tasks as well.

Added value of this study

Our findings showed the application of ChatGPT in clinical diagnostics. Synthetic cases created by experts in neurology were analyzed by ChatGPT in order to provide the most probable diagnoses. After cross-validation of the synthetic cases by neurological experts and medical doctors not related to neurology, the diagnostic accuracy of ChatGPT was measured. The large

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language model achieved similar results to the expert and surpassed the accuracy of general medical doctors. In certain cases, where even neurology experts failed to provide the correct diagnosis, ChatGPT successfully diagnosed the disease in 40% of the cases.

Implications of all the available evidence

Besides the large language models' usefulness in scientific writing, it might be an effective tool in clinical medicine to reduce the workload on medical doctors and to increase the experience of healthcare workers and patients. ChatGPT might be an exceptional augmentation for clinicians for diagnosing rare, atypical, and controversial neurological cases since the diagnosis of these diseases is often delayed or hindered.

Introduction

Artificial intelligence (AI) has a rich history in medicine since its first form as a rule-based decision-maker and became more and more accepted and spread with the progression of machine vision, specialized learning models, and natural language processing[1]. One of the most recently released AI, ChatGPT, a third iteration of a generative pre-trained transformer (GPT) became a controversial phenomenon in the scientific community. This freely accessible AI is an autoregressive large language model utilizing deep learning, the most advanced form of neural-network-based machine learning to produce astonishingly human-like texts. Since its release at the end of November 2022, millions of users composed essays, e-mails, and even novellas and movie scripts with the help of ChatGPT, furthermore recent studies showed its usefulness in the academic community. Most of these works focused on its capability to write abstracts and even whole manuscripts[2]. The versatility of such tools is undeniable, however, integrity and ethical concerns emerged. ChatGPT can answer factual questions with good precision, but in the case of scientific writing, the AI sometimes gives plausible-sounding results with incorrect or nonsense meanings[3]. A study published a couple of weeks after ChatGPT became freely available showed that almost half of the abstracts written by the AI

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passed the evaluation by reviewers[2]. Along the technological advances, there is an urgent need for evolving editorial policies, fortunately, the most prominent publishers are still integrating roles for using large language models in scientific writing[4,5]. Most of the research focuses on the possibilities of ChatGPT as an innovative tool aiding scientific writing, however, various options for medical application might be present as well. Besides their usefulness in multilingual communication with patients, large language models can be used in simple, yet time-consuming tasks, such as composing high-quality discharge summaries. Patel and Lam showed ChatGPT is capable to write these documents which usually stretch the junior MD (medical doctor) workforce and delay patients' discharge[6]. A recent study showed that the current knowledge of ChatGPT has passed all three modules of the United States Medical Licensing Examination, which, besides creating educational issues about medicine, raises questions about its capability as an effective tool in diagnostics in the near future[7,8]. Especially, in overwhelmed areas of medical care units, such as emergency medicine, where swift decision-making, triaging, and diagnostic certainty are key components for successful patient management. Approximately 9-15% of patients admitted to the emergency room show neurological symptoms, representing a significant ratio[9,10]. According to the work of Moeller and his colleagues, over one-third of the neurological cases in an emergency room were misdiagnosed[11], however, diagnostic uncertainty is not limited to emergency medical care scenarios. In a study conducted by Chimowitz and his colleagues, the bedside diagnostic accuracy was 77% among neurologists, where the diagnosis had to be made based on patient history and physical examination[12]. Here we aimed to measure the efficacy of ChatGPT as a diagnostic tool based solely on the patient history and neurological status of the synthetic patient data, representing real-life scenarios from the field of neurology.

Materials and methods

Participants

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Altogether, 12 medical doctors participated in the study from the University of Szeged, Hungary. Six participants worked as neurologist specialists (n=4) or neurological residents (n=2), thus they were sorted into the "experts" group. Furthermore, six general medical doctors were sorted into the "MDs" group. The members of the "MDs" group have not yet completed their specialty training and only received basic training in neurology as part of their undergraduate studies.

Synthetic data generation

Synthetic cases with patient history and a brief, focused neurological status (n=200) were generated by neurological experts (n=5) and structured into a life-like free-text form without abbreviations (Supplementary 1). The synthetic cases represented real-life scenarios and a wide range of neurological diseases, varying from the most common cases to rare ones (Table 1).

Major disease groups (n=200)	
Neurovascular diseases	n=43
Neuroinfectious diseases	n=7
Neuromuscular and peripheral nerve disorders	n=23
Neurodegenerative disorders	n=24
Demyelination disorders of the CNS	n=10
Metabolic disorders	n=7
Headache syndromes	n=14
Spinal cord and radicular syndromes	n=8
Neurooncological disorders	n=11
Epilepsy and seizures	n=8
Hereditary neurological disorders	n=17
Other disorders	n=28

Table 1.: *List of the disease categories for the synthetic cases*

In a few cases, the disorder was not limited strictly to the field of neurology, however, the patient showed neurological symptoms. The synthetic cases were sorted into acute (n=85) and non-acute (n=115) cases. A case was labeled as "acute", when without specific treatment within 24 hours, the disease would have potentially led to irreversible and disabling symptoms or life-threatening conditions (e.g. acute stroke, meningitis, subarachnoid hemorrhage, etc). All cases were cross-validated, where each neurological expert and medical doctor had to identify the original diagnosis for each case, based solely on the patient's history and neurological status. In

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some cases, theoretically, more than one diagnosis could be correct. However, each participant was instructed to give the most likely diagnosis for each case. In most cases only the specific diagnosis was accepted as a "matching diagnosis", however, we did not further differentiate the acute stroke cases, since the clinical/bedside differentiation of ischemic and hemorrhagic stroke is highly uncertain[13]. Consequently, in certain cases, the diagnoses provided by ChatGPT were merged together (e.g. separate diagnoses, such as "acute ischemic stroke" and "acute hemorrhagic stroke" were merged together as "acute stroke").

Generation of the AI-given diagnoses

The previously described synthetic cases (n=200) were fed into ChatGPT (developed by OpenAI (https://openai.com/), accessed between February 8–17, 2023). We asked the large language model to list the top five most probable diagnoses in decreasing order of probability, then we created three groups that represented the most probable diagnosis (ChatGPT Top1), the three most likely (ChatGPT Top3), and the five most likely diagnosis (ChatGPT Top5). In certain cases, the task to give the five most probable diagnoses was forced on the AI, however, the answer of ChatGPT stated that the most probable diagnosis is the correct one with maximum certainty.

Results

To evaluate the diagnostic efficacy of ChatGPT, we determined the ratio of correct diagnosis in the MDs, experts, and ChatGPT groups. The most likely diagnosis provided by ChatGPT matched the original diagnosis in 68·5% of the cases, which surpasses the success ratio of the MDs group (57·08% ± 4·8%) but does not reach the ratio of the expert group (81·58% ± 2·34%) (Figure 1). However, the five most probable diagnoses provided by ChatGPT included the correct diagnosis in 83·5% of the cases which is nearly identical to the success rate of the expert group.

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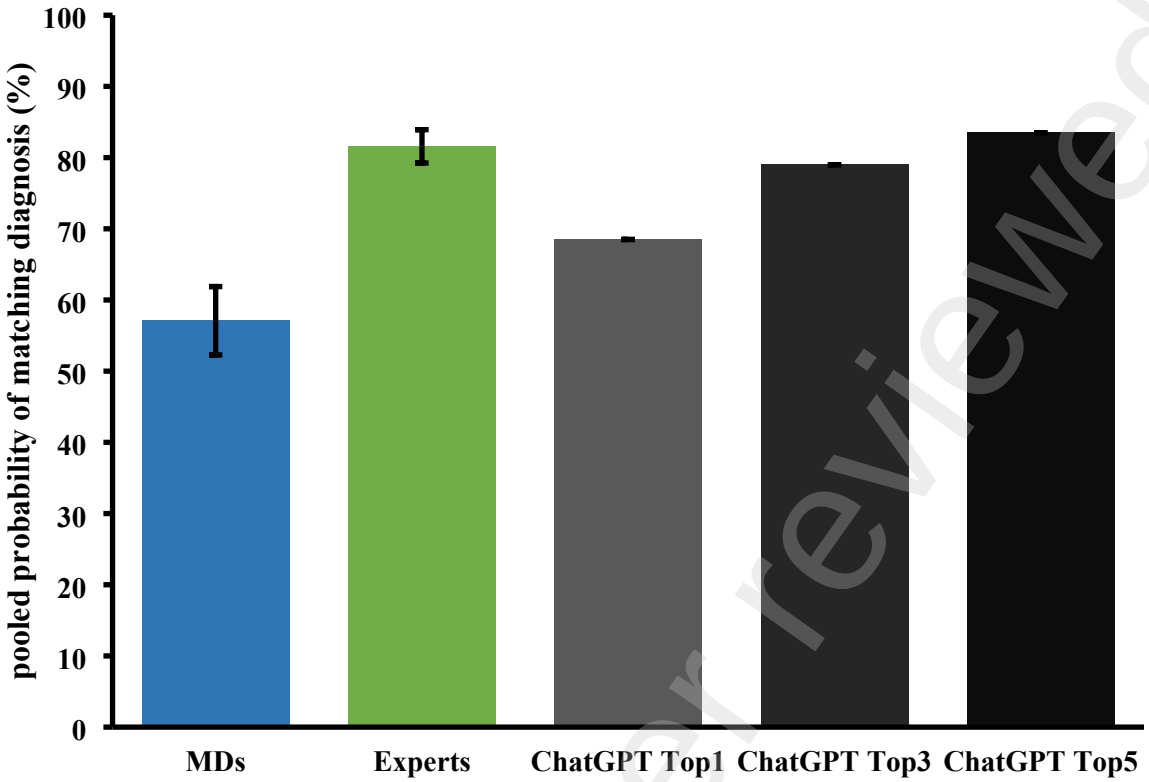

Figure 1.: *Pooled ratio of successful diagnosis by medical doctors (MDs), experts, and ChatGPT. In the case of the ChatGPT group, three columns represent the most probable (ChatGPT Top1), three most probable (ChatGPT Top3), and five most probable diagnoses (ChatGPT Top5). Experts achieved the highest diagnostic accuracy. ChatGPT Top1 did not meet the level of the expert, however, it surpassed the success ratio of the MDs. Considering the three and five most probable diagnoses suggested by the ChatGPT, the success ratio increased and reached the level of experts. Since ChatGPT is a single entity, there is no within-group variance, therefore statistical analysis is not recommended. All of the data represents mean ± standard deviation.*

Acute neurological disorders often present with drastic and well-characterized symptoms, furthermore, these cases have a more abundant literature background which is essential for training neural networks. Therefore, the diagnostic accuracy of ChatGPT in the subgroup of the acute cases (n=85) was also examined. Interestingly, all three groups solved the cases with similar accuracy. The most likely diagnosis provided by the AI matched 71·8% of the original diagnoses, which is nearly indistinguishable from the success ratio of the MDs (68·8% ± 6·21%) and even from the expert group (72·5% ± 8·51%) (Figure 2A). In the subgroup of acute neurological cases, the 5 most probable diagnoses included the correct one in 85·9% of the cases, which surpasses the diagnostic accuracy of the expert group. The remaining non-acute scenarios (n=115) represented a mixture of cases, where patients might be admitted to the emergency care unit due to subacute symptoms or the neurological outpatient unit with chronic

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disorders. As expected, in the non-acute disease group the diagnostic accuracy was lower in all three (MDs, experts, and ChatGPT) groups compared to the acute neurological cases. Surprisingly, ChatGPT achieved the highest diagnostic accuracy (66·09%, based on the most probable diagnosis provided by ChatGPT) and the experts' diagnosis showed a similar success ratio (64·49% ± 8·84%) (Figure 2B). Both groups considerably surpassed the success rate of the MDs group (48·41% ± 6.43%).

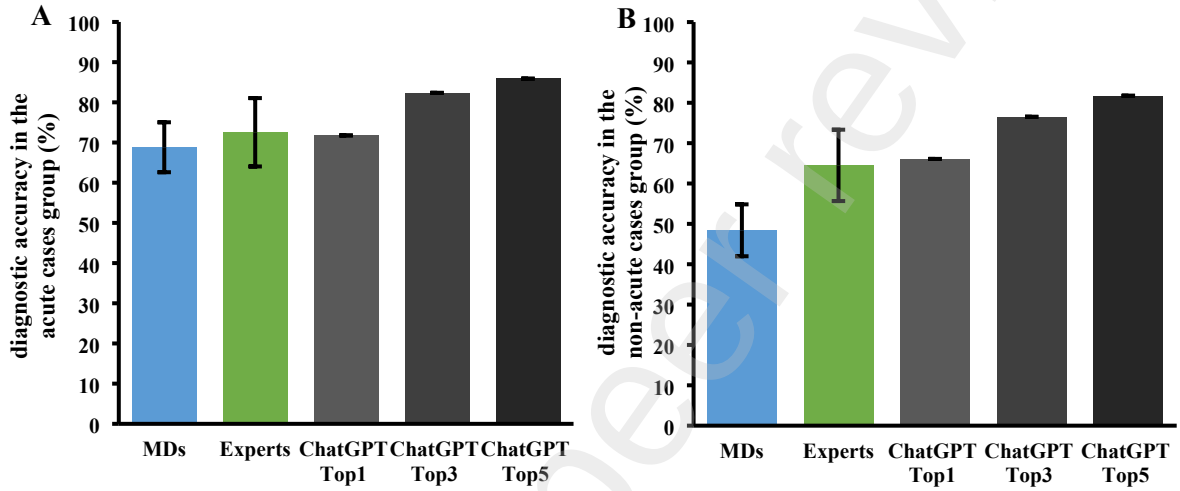

Figure 2.: *Pooled success ratio of correct diagnosis for acute (A) and non-acute cases (B) by medical doctors (MDs), neurological experts, and ChatGPT. Three columns of ChatGPT results represent the most probable (ChatGPT Top1), the three most likely (ChatGPT Top3), and the five most probable diagnoses (ChatGPT Top5). Interestingly, MDs, experts, and the most likely diagnosis by ChatGPT have an almost identical probability for successful diagnosis in the case of acute disorders. However, the ratio of successful diagnoses was drastically decreased in the MDs group if the initial diagnosis was a non-acute disease. Regardless of the disease group, the accuracy of the three or five most likely diagnoses made by ChatGPT surpassed all of the other groups. Since ChatGPT is a single entity, there is no within-group variance, therefore statistical analysis is not recommended. All of the data represents mean ± standard deviation.*

Obviously, each participant and the ChatGPT made incorrect diagnoses, thus the similarity of these errors between humans and the AI was also evaluated. All false diagnoses from the participants were collected (n=367) and each wrong conclusion was compared to the misdiagnoses made by the AI for the same case. Considering the most probable suggestion of the ChatGPT, almost one-third (26·98%) of the misdiagnoses were identical to that of the human participants (Figure 3). Regarding the five most probable diagnoses of ChatGPT, the accordance of the wrong diagnoses between medical doctors and the AI increased to 37·87%.

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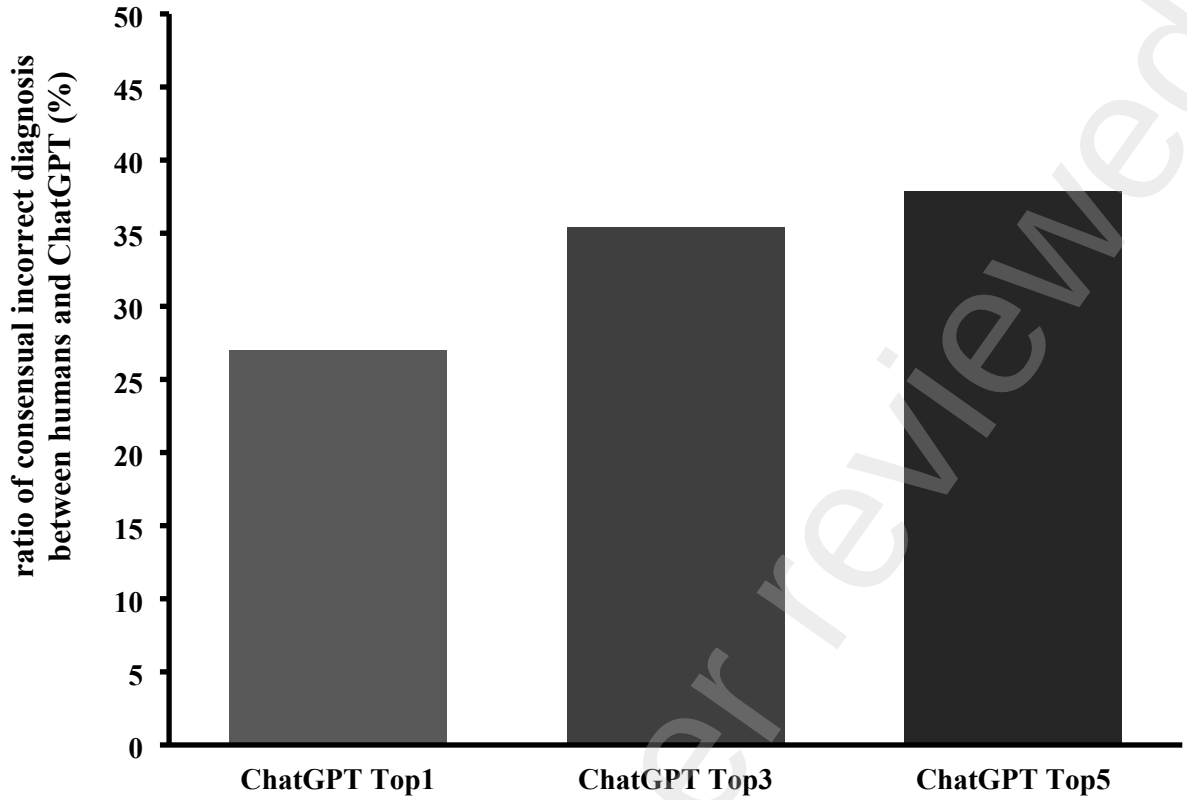

Figure 3.: *Ratio of consensual incorrect diagnosis between humans and ChatGPT. Almost one-fourth of the incorrect diagnoses made by AI (ChatGPT Top1) matched those given by medical doctors (MDs) and experts. Obviously, this ratio increased further if we examined the three (ChatGPT Top3) and the five (ChatGPT Top5) most likely diagnoses given by ChatGPT.*

Additionally, in a few cases, all six experts failed to provide an accurate diagnosis. These outliers were referred to as unsolved cases (n=10). Most of these cases were rare neurological disorders (e.g. spinal muscular atrophy type 4, titin-associated myasthenia gravis, antineutrophil cytoplasmic antibody vasculitis-associated mononeuritis multiplex, Pompe disease, Bickerstaff encephalitis), where the differential diagnosis is heavily reliant on further examinations and the exclusion of alternative diagnoses. Astonishingly, the most probable diagnosis of ChatGPT matched to original diagnosis in 40% of these cases, and the five most probable AI-given answers included the correct diagnosis in 60% of the cases (Figure 4).

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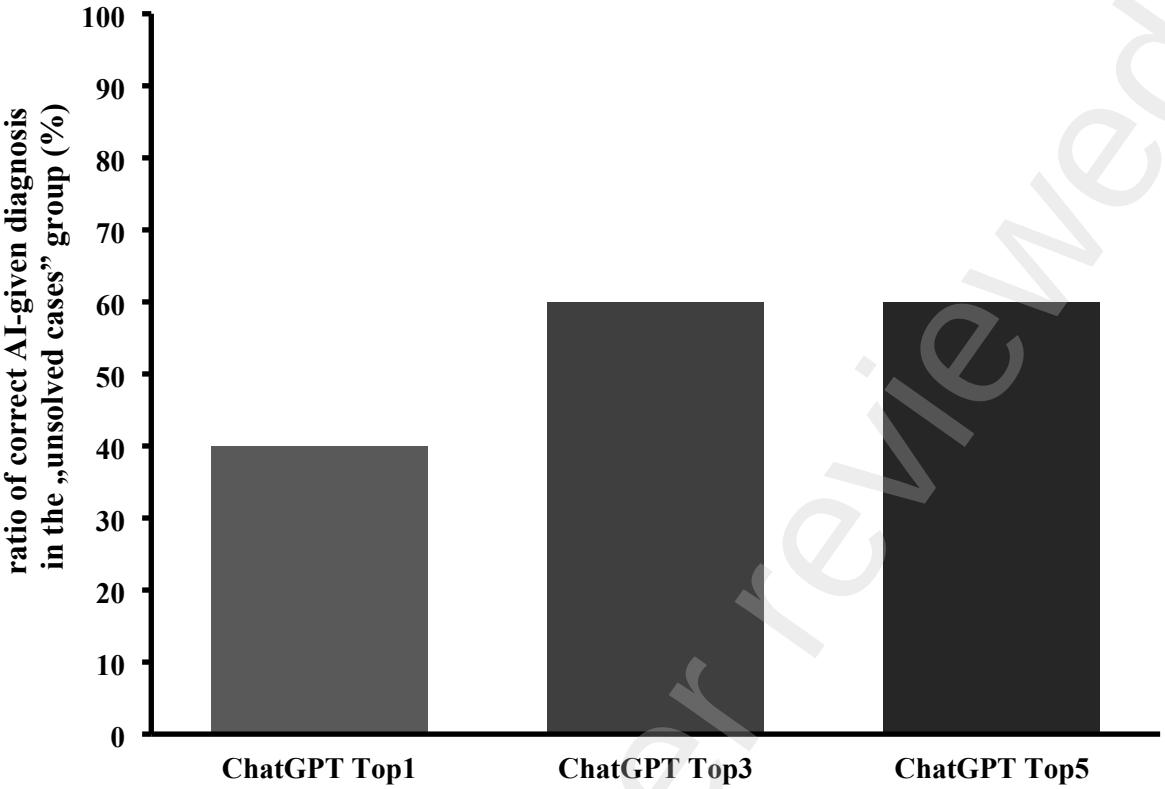

Figure 4.: *Ratio of correct diagnosis by ChatGPT in the unsolved cases. All of the cases without a correct diagnosis by the experts have been collected (n=10), then the success ratio of AI in these cases has been examined. Astonishingly, the most probable diagnosis by the AI (ChatGPT Top1) was correct in 40% of the cases, and the three (ChatGPT Top3) and five (ChatGPT Top5) most likely diagnoses were accurate in 60% of the unsolved cases.*

Discussion

Surprisingly, novel technical advances infiltrate science relatively slowly, especially in medicine. Since the dawn of machine learning, only a few AI tools have been translated into clinical practice due to slow or complicated applications in real-life scenarios[14]. However, user-friendly AIs like ChatGPT might revolutionize numerous fields including education[7,15], informatics[16], scientific publishing[5], and even healthcare[17]. As our results suggest, ChatGPT can be a valuable tool in medicine indeed, since it shows promising diagnostic capability besides its usefulness in composing discharge documents[6], choosing the appropriate antimicrobial agents[18], and creating radiological reports[19]. While the use of AIs in modern medicine is highly relevant and potentially multifaceted, in its current form should only be considered as an augmentation tool in the traditional workflow of healthcare. Using generative

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AIs like ChatGPT as a supportive tool can alleviate a significant burden on doctors, especially on the stretched junior MD workforce. While our results indicate an impressive diagnostic accuracy, all suggestions made by ChatGPT should further be evaluated by a medical expert to screen for potential misdiagnoses and critical diagnostic flaws. It is also noteworthy, that in our experimental setup, the AI was exclusively dependent on the data (patient history and neurological examination) provided by the neurological expert. Since this data is also heavily reliant on the experience and expertise of the examiner, the currently reported diagnostic accuracy of ChatGPT only reflects the clinical scenario, where the patient was already examined by a neurologist. Since the diagnostic accuracy of ChatGPT is likely dependent on the quality of the data provided by the examiner, thus the AI could prove to be a more efficient supporting tool in the hands of a specialized expert. We initially hypothesized that ChatGPT could support the triaging process in acute neurological scenarios, which is supported by our results, as the diagnostic accuracy was comparable to that achieved by medical doctors and neurologists. On the other hand, we expected to see a drastic reduction in the diagnostic accuracy in non-acute neurological scenarios, as the clinical diagnosis of rare neurological disorders is also often delayed or hindered[20–24]. Even though the diagnostic accuracy of ChatGPT was lower than in the acute disease subgroup, it still surpassed the success ratio of the participants. Even more surprisingly, ChatGPT successfully diagnosed some of the unsolved cases. This could potentially indicate an important role for AI in the diagnosis of rare, atypical, and controversial neurological cases, furthermore, generative AI could accelerate the diagnosis of such disorders. In the future, AI will most likely reshape medicine by improving both the patients' and medical doctors' experiences, especially in overwhelmed fields and/or areas requiring fast decision-making like oxiology and emergency care. On the other hand, using AI in medicine, despite the potential benefits of augmenting and automatizing medical tasks with AI, raises major ethical, integrity, and data safety and privacy concerns[25]. Rapid

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ethical and jural revision of existing guidelines and laws is necessary to overcome these challenges.

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Supplementary information

Supplementary Information is available for this paper.

Acknowledgments

The project and R.P. were financially supported by the OTKA FK_22 143326 grant from the National Research, Development, and Innovation Office of the Hungarian Government. R.P. was financially supported by the „National Talent Programme" scholarship with the financial aid of the Ministry of Human Capacities (NTP-NFTO-22-B-0027).

Authors contributions

Conceptualization: R.P., Data curation: B.N., V.M., A.Cs., L.Sz., P.H. D.H. M.T., F.M., B.E-F., D.T., Zs.B., P.K., Formal analysis: T.F.P., Z.K., Investigation: T.F.P., Z.K., Methodology: R.P., B.N., T.F.P., Project administration: R.P., Resources: R.P., Supervision: R.P., Validation: R.P., L.S., P.K., Writing the original manuscript: B.N., T.F.P., R.P., Review: R.P., L.S., P.K.

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Competing interests

The authors declare that they have no competing financial interests.

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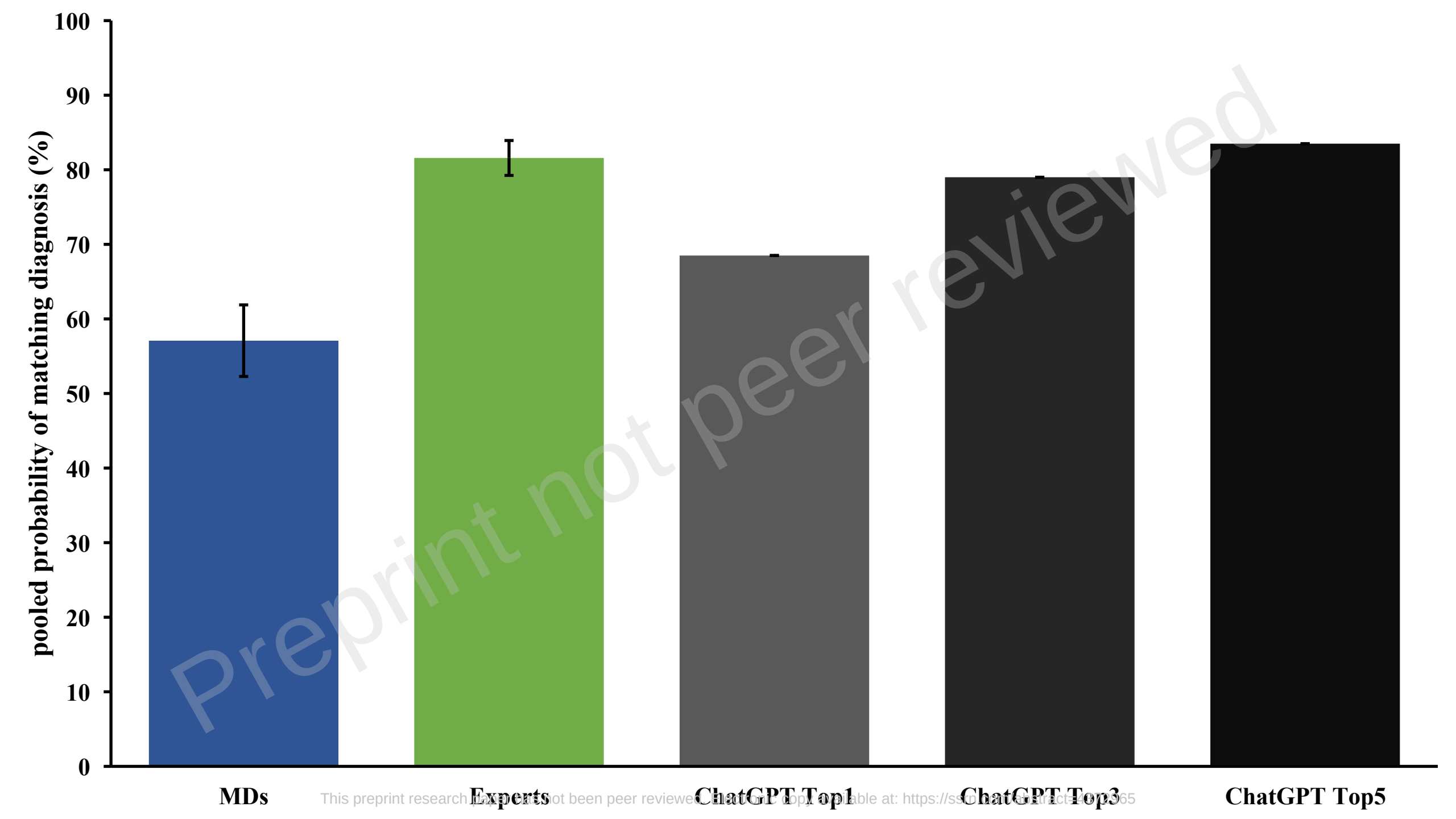

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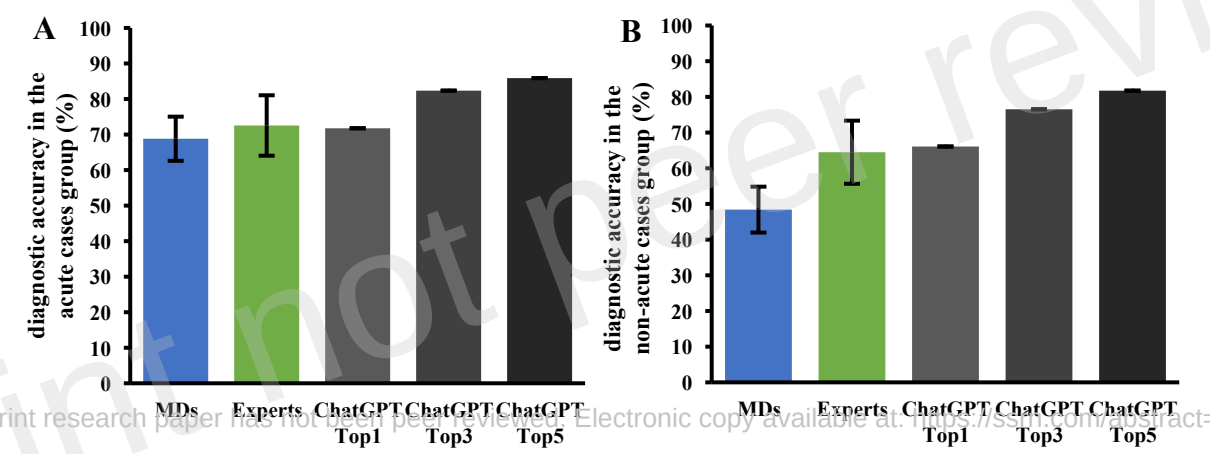

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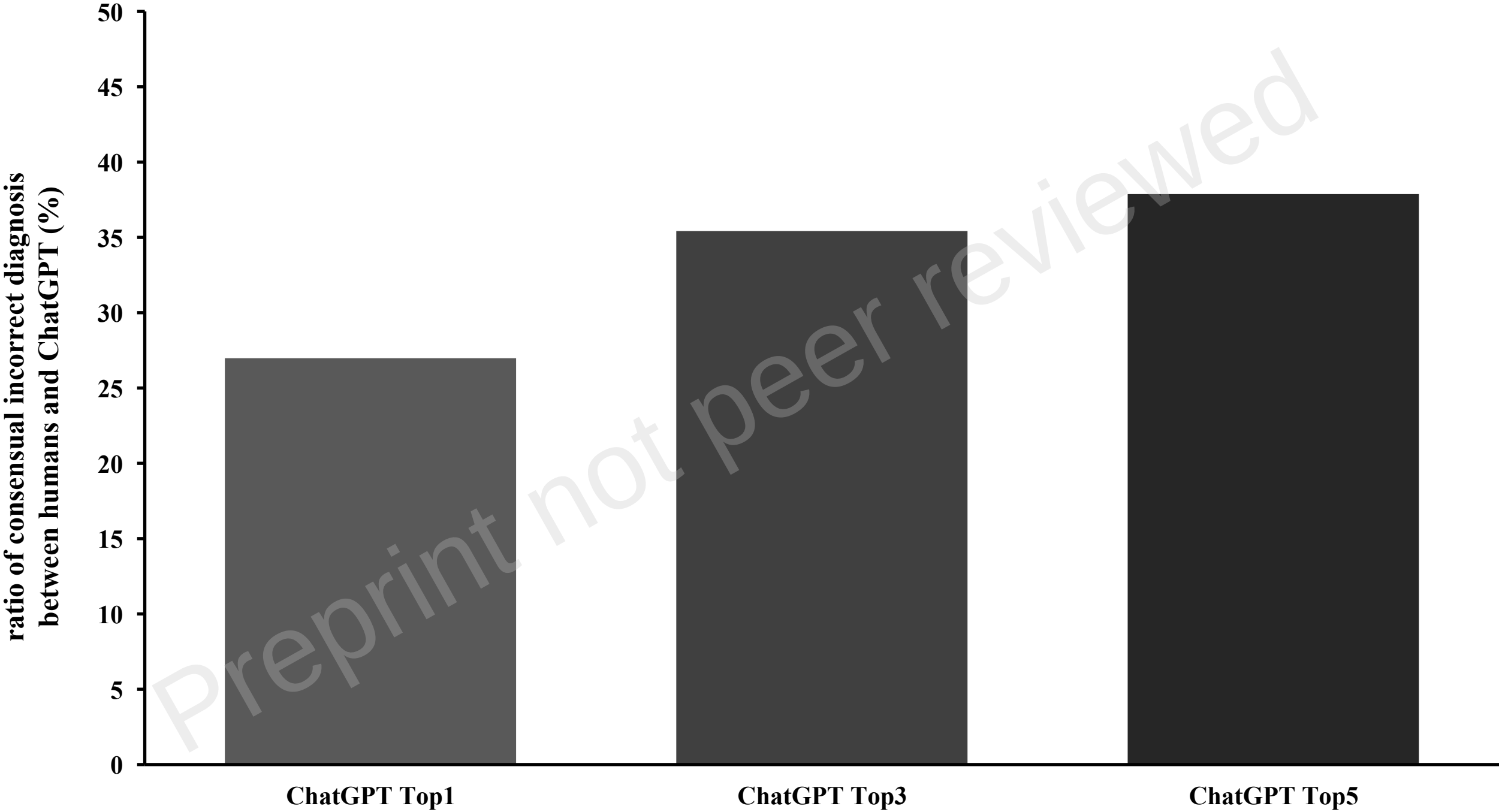

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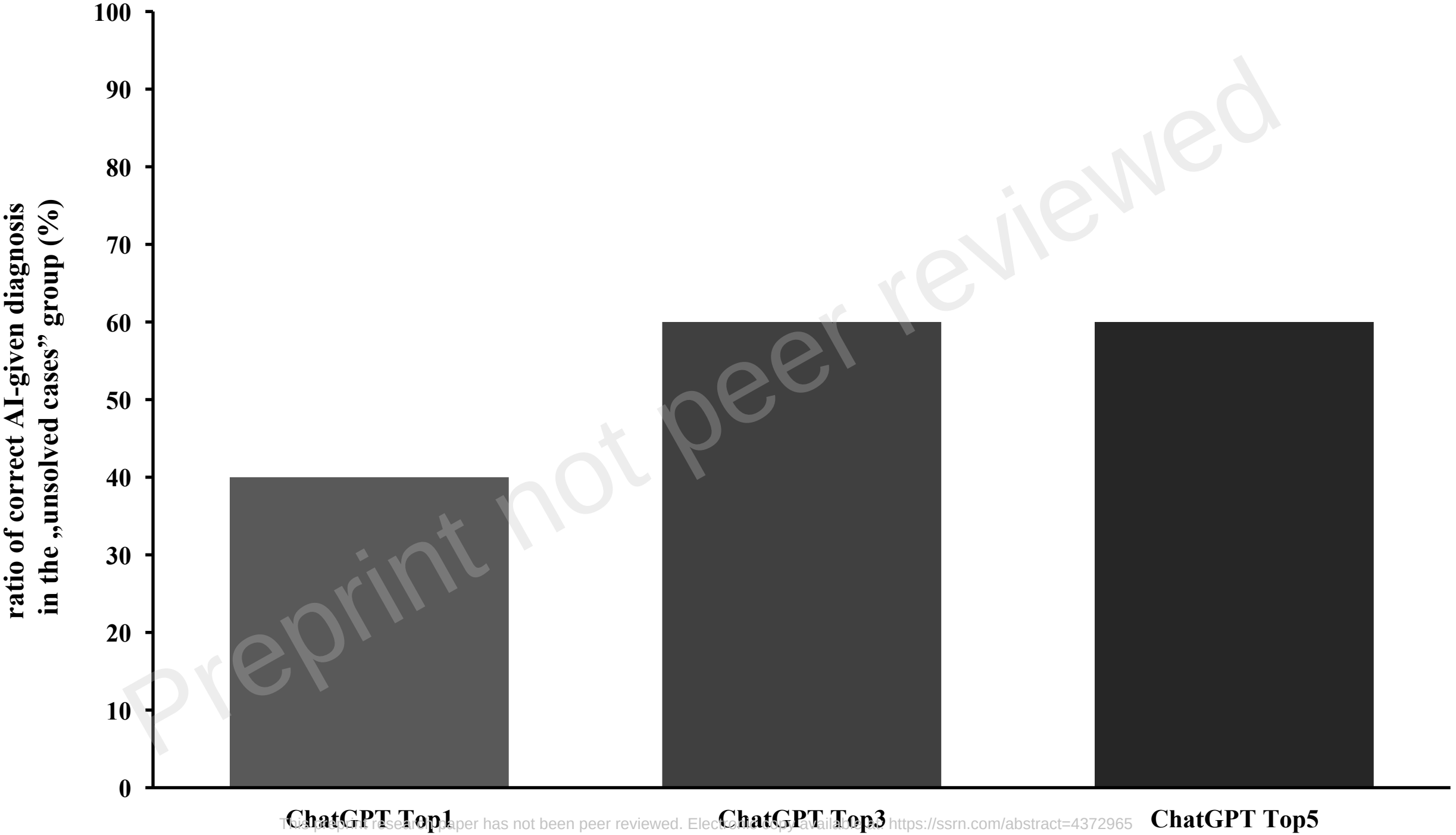

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Major disease groups (n=200)	
Neurovascular diseases	n=43
Neuroinfectious diseases	n=7
Neuromuscular and peripheral nerve disorders	n=23
Neurodegenerative disorders	n=24
Demyelination disorders of the CNS	n=10
Metabolic disorders	n=7
Headache syndromes	n=14
Spinal cord and radicular syndromes	n=8
Neurooncological disorders	n=11
Epilepsy and seizures	n=8
Hereditary neurological disorders	n=17
Other disorders	n=28

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